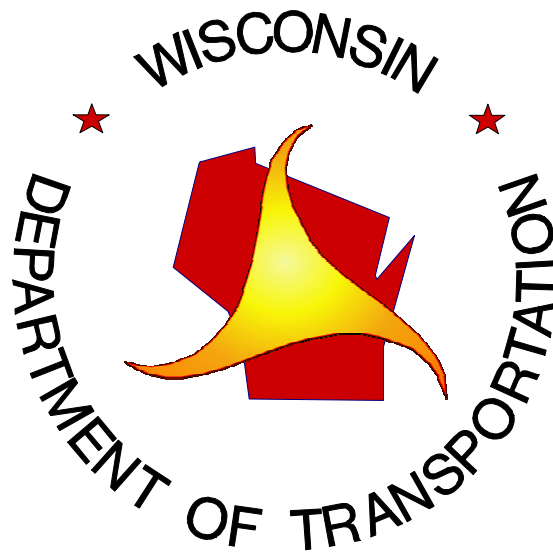


**WI/FEP-09-96**

**EXPERIMENTAL CULVERT PIPE, STH 80  
JUNEAU AND WOOD COUNTIES, WISCONSIN**

**FINAL REPORT**



**NOVEMBER 2003**

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		<b>14. Sponsoring Agency Code</b>	
<b>15. Supplementary Notes</b>			
<b>16. Abstract</b> <p>Culvert pipes of aluminum, aluminized steel, polymeric coated galvanized steel and epoxy bonded steel were placed at three sites in central Wisconsin in 1981 and monitored for their corrosion resistance. Galvanized steel apron end walls were attached to the pipes as a means of comparison of corrosion rates with zinc galvanized steel. The three sites selected were in areas where strong corrosiveness to zinc galvanized steel pipe was highly likely. Field tests of soil and water at the sites were made annually including pH, electrical resistivity and oxidation-reduction potential of the soil and water, dissolved oxygen content of the water and sulfide content of the soil.</p> <p>The pipes experienced corrosion originating from a variety of conditions including low pH of the soil and water, anaerobic sulfate reducing bacteria in the soil and water, and road salt. In comparing the performance of the four culvert types, the polymeric coated galvanized steel pipes appeared to best resist corrosion. None of the pipes were perforated and removal of the coating was localized to the vicinity of exposed rivet heads and section ends. The epoxy bonded steel pipes did not perforate but lost considerable coating at the two sites of flowing water and experienced advanced corrosion at joints at the site of equalizer pipes. This type of coating is no longer used. The aluminized steel pipe experienced localized perforation and localized pitting of the steel cores and inverts at localities of organic material. The protective cover of aluminum is ascribed to the development of an aluminum oxide coating on the metal and this coating appears to be degraded in more strongly reducing environments. The aluminum pipe evidenced the most severe distress and resulted in several instances of failure due to corrosion in forms of thinning of the metal roofs, perforations in the roofs, and coatings of white precipitate on the inner roofs of the pipes. This type of corrosion appears to be attributable to the presence of NaCl in chemical deicers (road salt). The aluminum pipes have, however, proved to be immune to corrosion in the natural environment. There has not been a reported case of perforation of an invert of an aluminum pipe from the water side in Wisconsin, but there were several aluminum pipes perforated from the soil side in areas of wet organic sandy soil. These pipes had replaced the zinc galvanized steel pipe that had been corroded by the actions of anaerobic sulfate reducing bacteria in the water. At this time, some aluminum culvert pipes with protective covering laid over the top are being installed in Wisconsin. The galvanized steel apron end walls unexpectedly experienced advanced corrosion at all three sites, and some perforation at one site.</p> <p>It appears that the type of pipe least susceptible to corrosion caused by moist organic soil, at sites where tests for anaerobic sulfate reducing bacteria in the soil is frequently positive, is a pipe with an organic barrier coating, such as polymeric coated steel.</p>			
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**EXPERIMENTAL CULVERT PIPE, STH 80  
JUNEAU AND WOOD COUNTIES, WISCONSIN**

**FEDERAL EXPERIMENTAL PROJECT # WI 80-02,03,04**

**FINAL REPORT # WI/FEP-09-96**

NOVEMBER 2003

PREPARED BY

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## INTRODUCTION

This project was approved for Federal Aid participation by the Federal Highway Administration (FHWA), as submitted by the Wisconsin Department of Transportation (WisDOT) in 1980 (see Appendix A). The objective of this project was to observe the corrosion resistance of four types of culvert pipes which were not in widespread use in Wisconsin at the time this project was initiated in 1981. The pipes were aluminum, aluminized steel with spiral crimped seams, polymeric coated galvanized steel pipe and epoxy bonded steel pipe.

It had previously been determined that much of central and northern Wisconsin was very corrosive to zinc galvanized steel pipe by virtue of the activity of anaerobic sulfate reducing bacteria (SRB) in the surface water<sup>1</sup>, in addition to the more common corrosive parameters of low pH and electrical resistivity of soil and water at a culvert site and the activity of SRB bacteria in organic soil at a culvert site. Therefore, galvanized steel apron end walls were attached to the experimental pipes as a means of comparison of corrosion rates with zinc galvanized steel. Three sites on STH 80, in Juneau and Wood counties, were selected for this study on the basis of strong corrosiveness to zinc galvanized steel pipe. The three sites are located in the north central part of a large former glacial lake basin in central Wisconsin. Soils on the project are primarily fine sands and silts covered by more recent black organic deposition. Vegetation is currently characterized by areas of marsh and by red oak and jack pine and additionally by white birch, sugar maple and black spruce. The experimental pipes were installed along STH 80 at stations 713+36 and 976+40 in Juneau County and station 1111+70 in Wood County. Stations 713+36 and 976+40 each had two culvert pipes. Each of these pipes were comprised of two types of pipe, joined and sealed in the middle to form one continuous pipe. Station 1111+70 had four individual pipes installed, one of each type.

LOCATION	# OF PIPES	PIPE #1	PIPE #2	PIPE #3	PIPE #4
Station 713+36	2	epoxy bonded steel & aluminized steel	aluminum & polymeric coated galvanized steel	N/A	N/A
Station 976+40	2	epoxy bonded steel & aluminized steel	aluminum & polymeric coated galvanized steel	N/A	N/A
Station 1111+70	4	aluminum	aluminized steel	polymeric coated steel	epoxy bonded steel

Several instances of failure of aluminum pipe on STH 54 in Wood County in 1994, due to corrosion of the pipe roofs attributed to the action of road salt, prompted an inspection of existing aluminum culvert pipe<sup>2</sup>. That inspection revealed that many of the aluminum culvert pipes on STH 80 were also distressed. The southern section of STH 80 was scheduled for resurfacing with flexible pavement in 1995. It was decided to remove both composite pipes at sites 713+36 and 976+40, providing an opportunity to examine the pipes that was not available while they were

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1 Patenaude, Robert (1988). *Corrosion Evaluation of Experimental Metal Culvert Pipe in Wisconsin*. Progress Report.

2 Patenaude, Robert (1993). *Corrosion of Aluminum Drainage Structure*. WisDOT Correspondence Memorandum.

installed and filled with water. The four pipes at station 1111+70 were not removed and were not part of the resurfacing project.

This study encountered a wide range of pH, electrical resistivity, redox and dissolved oxygen values at each culvert site. Testing for each of these factors was done at the same time each year, in May, in an attempt to minimize the impact of seasonal changes. Laboratory grade instruments were used for the field tests. An Orion model 399A analog meter was used for the pH and redox measurements. The meter calibration was checked with buffer solutions between pH readings. Electrical resistivity measurements were made with a Nilsson model 400 soil resistance meter and a soil box of the type described in test method No. Calif. 643-C. A yellow Springs model 51B dissolved oxygen (D.O.) meter was used for D.O. measurements. There is a suggestion of cycle lengths of several years in the pH and resistivity data. The range of these values throws into question the efficacy of field tests for the prediction of corrosiveness at new culvert sites.

### **STATION 713+36, JUNEAU COUNTY**

The southern site, station 713+36, was selected because of low pH values of the soil and the advanced stage of corrosion of the existing 36 inch (900 mm) 12 gage zinc galvanized steel culvert pipe. This is essentially a site of equalizer pipes in an area of shallow groundwater. Water levels have varied from overtopping of the pipes to the site being dry, with the pipes usually being one-third to one-half full of water. Water at this site is more commonly standing than flowing. Excavation of the ditches at the site in 1992 created shallow basins at the ends of the pipes where none existed previously. Soil at the site is basically a fine sandy silt with an organic accumulation at the surface. The original 12 gage galvanized steel pipe had large holes along the flow line in 1975 (see photo on page 4). In 1975, the corrosion was attributed to low pH of the soil.

The following table lists results of on-site testing done at culvert site 713+36 and the results of three water sample analyses made for chloride and sodium at the University of Wisconsin Extension Soil and Plant Analyses Laboratory in Madison. The on-site tests indicate a range of values. Water was commonly standing at this site, and at times there was algal growth that may account for some higher D.O. values. The soil pH was commonly acidic but may vary with the ratio of mineral soil to organic material in the sample. The H<sub>2</sub>S test of the soil consists of adding diluted hydrochloric acid to moist soil and detecting the generation of H<sub>2</sub>S by smell and with lead acetate paper. The assumption is that sulfide in the soil is produced by anaerobic sulfate reducing bacteria. As the data indicates, this test is usually positive at this site when pH values are above 5. The chloride and sodium values are rather high for May and reflect the condition that water is commonly standing at this site. The relatively high Cl and Na values are probably the principal cause of the relatively low electrical resistivity values of the water at this site.

Photos of this site are found on pages 4 through 12.

# ON SITE TESTS AT STATION 713+36, STH 80, JUNEAU CO.

DATE	pH		OHM cms		REDOX, MV		D.O. (ppm)	H <sub>2</sub> S test (soil)
	SOIL	WATER	SOIL	WATER	SOIL	WATER		
6/75	4.7	5.6	14,000	1,600	+200	+300		
6/81	6.2	5.8	14,000	5,000	+320	+480	7	positive
INSTALLATION OF EXPERIMENTAL PIPE								
5/82	4.4	6.1	6,200	5,300	+400	+470	5	negative
5/83	4.3	4.5	8,500	5,400	+390	+460	3	negative
5/84	4.7	6.2	8,500	5,200	+430	+510	8	negative
5/85	4.4	6.1	3,600	3,000	0	+460	9	faintly positive
5/86	4.6	6.4	6,500	2,300	+400	+500	10	weakly positive
5/87	7.0	6.6	6,600	2,600	+200	+300		faintly positive
5/88	5.9	Dry	5,700		+200			strongly positive
5/89	5.6	6.0	8,700	2,500	+350	+500	10	strongly positive
5/90	3.9	5.1	4,100	4,000	+340	+500	7	negative
5/92	4.0	5.3	2,000	2,100			7	negative
6/93	3.9	4.7	3,300	3,200	+200	+480	4	negative

D.O. = Dissolved Oxygen

### Sodium and Chloride Values

DATE	Cl (ppm)	Na (ppm)
5/85	151.0	90.8
5/89	125	83.9
5/90	75.5	41.6



Station 713+36. Original 12 gage galvanized steel pipe. Note holes in side of invert. Corrosion mostly scale. Tag 1941. 1975





Station 713+36. Some pitting of the cladding of the aluminum pipe. Apparently a reaction with organic-rich soil. Outlet. 1986



Station 713+36. Oxidation of uncoated rivet heads and section ends of polymeric coated pipe. Note corrosion of endwalls. Inlet. 1987





Station 713+36. Some oxidation of the weld area on the lock seam of the aluminized steel pipe. This did not change in later years. Outlet. 1987



Station 713+36. Some separation of polymeric coating from steel at inlet end of pipe. 1992



Station 713+36. Some separation of polymeric coating from steel at uncoated rivet heads and section heads. 1994



Station 713+36. Perforation of galvanized steel apron endwall attached to aluminized steel pipe. 1994





Station 713+36. Loss of epoxy coating at first joint of epoxy bonded pipe and advanced corrosion of steel. This part of pipe commonly under water. Inlet. 1994





Station 713+36. View through polymeric coated pipe to aluminum pipe. Pipes joined near center of road. White precipitate is on roof of aluminum pipe. Precipitate greatest under pavement, with little precipitate under shoulder and back slope. Precipitate enters through roof of pipe. This condition is commonly an indication of moderate corrosion of the soil side of the pipe at the roof and is apparently related to use of NaCl deicer. Brown coloration on lower part of polymeric coated pipe is stain. 1994





Station 713+36. Pipe removal. This was formerly the inlet end. Note separation of polymeric coating. The ends of the steel sections were not coated.



Station 713+36. Invert on side. Note separation at section ends. 1995





Station 713+36. Perforations and white precipitate on roof of aluminum pipe.



Station 713+36. Close-up of corrosion on roof; aluminum pipe. 1995





Station 713+36. Aluminized steel. Localized areas of organic-rich fill adhering to pipe.



Station 713+36. Beneath organic-rich fill, barrier coating removal with some small 1/8 inch pits through to steel core. 1995



## **SITE 976+40, JUNEAU COUNTY**

This site is on a small stream down stream from a marshy area. This originally was a good site until beavers dammed the stream. Initially a dam was built just beyond the pipes on the upstream end. The beavers next built a dam at the inlet of the pipes, covering the epoxy bonded inlet of the epoxy bonded/aluminized steel pipe, and finally the beavers built a dam inside of the epoxy bonded pipe. Water flow through this pipe was virtually stopped. Water levels at the pipes were raised, water clarity diminished, and the amount of organic material at the site increased. The inlet pipes, the epoxy bonded pipe and the polymeric coated pipe, were slightly damaged during removal of the dams. The original pipe here was a 12 gage, 42 inch (1067 mm) galvanized steel culvert pipe with a 1941 tag and with the invert separated from the remainder of the pipe by perforations along the flow line. In 1975, the corrosion at this site was attributed to the activity of SRB bacteria in the water. Low Cl and Na values at this site reflect the condition that water was running at the site.

The field data indicates that the soil at this site is commonly less acidic than the soil at site 713+36, and also that the water is characterized by higher electrical resistivity. This would suggest a somewhat less corrosive site than station 713+36, but corrosion rates for the original pipes were similar. In 1975, the corrosion at this site was attributed to the activity of SRB bacteria in the water, and the modules characteristic of this type of corrosion were also in evidence on the new galvanized steel end walls and on the exposed steel of the epoxy bonded pipe. It was previously determined that in Wisconsin this corrosion mechanism is active if the water alkalinity is less than 120 mg/l and very active if the water alkalinity is less than 80 mg/l. A field test here in 1990 indicated water alkalinity of 75 mg/l and a field test in 1993 indicated water alkalinity of 25 mg/l. Low Cl and Na values reflect the condition that water is commonly running at this site.

Photos of this site are found on pages 15 through 22.

**STATION 976+40, STH 80, JUNEAU CO.  
ON SITE TESTS**

DATE	pH		OHM cms		REDOX, MV		D.O. (ppm)	H <sub>2</sub> S test (soil)
	SOIL	WATER	SOIL	WATER	SOIL	WATER		
10/75	6.5	6.5	3,200	13,000				weakly positive
5/81	7.1	6.6	1,100	10,000	+100	+430	8.7	negative
INSTALLATION OF EXPERIMENTAL PIPE								
9/81	6.1	6.8	4,800	4,400	+400	+400	2.0	negative
5/82	6.2	6.4	1,650	10,000	+150	+400	2.5	strongly positive
5/83	4.9	5.4	8,000	20,000	+60	+450	6.5	negative
5/84	6.2	6.8	3,900	18,000	+160	+480	12.0	strongly positive
5/85	6.9	6.1	1,500	12,000	0	+480	5.0	strongly positive
5/86	6.5	6.9	1,500	3,350	-30	0	1.0	strongly positive
5/87	7.3	7.0	6,700	5,930	+70	+180	---	strongly positive
5/88	6.4	6.5	3,150	5,100	+50	---	3.0	weakly positive
5/89	5.6	6.5	9,400	13,400	+250	+450	10.0	negative
5/90	5.7	5.6	11,400	12,750	+400	---	5.0	faintly positive
6/93	6.4	5.2	1,300	15,100	+40	+550	7.6	positive

D.O. = Dissolved Oxygen

### Sodium & Chloride Values

DATE	Cl (ppm)	Na (ppm)
5/85	2.0	1.7
5/89	5.5	4.0
5/90	6.0	3.9



Station 976+40. Original 12 gage galvanized steel pipe. Note nodules along flow line produced by sulfate reducing bacteria. Invert separated from remainder of pipe. 1975



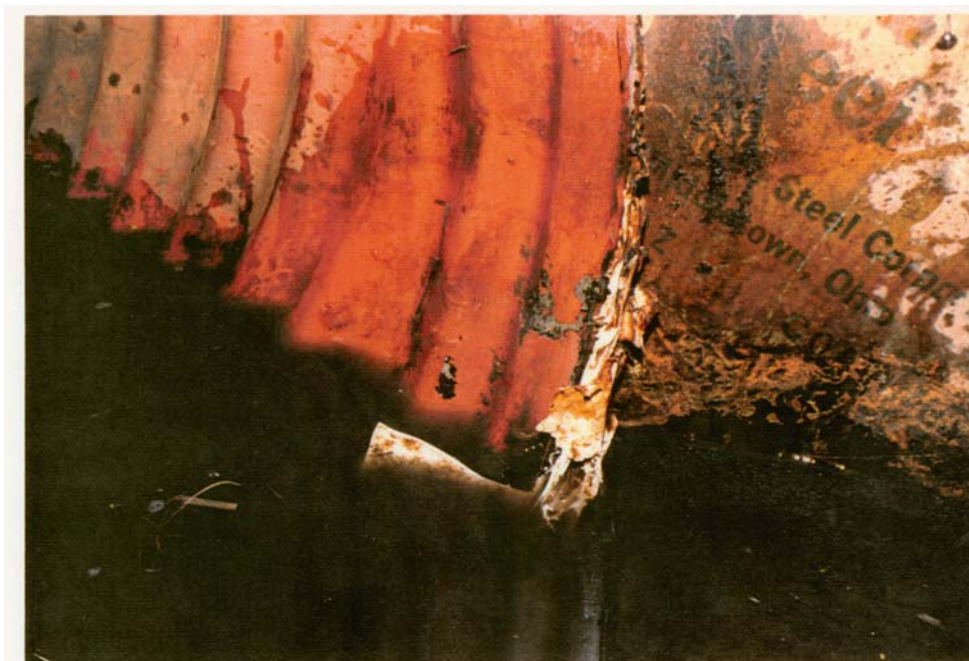
Station 976+40. SRB nodules at water line on galvanized steel apron endwalls. 1985



Station 976 + 40. One of recurring beaver dams at inlet, recently removed. Water is commonly too high to permit inspection of pipes. 1987



Station 976+40. Epoxy bonded pipe.  
Loss of epoxy at inlet of pipe. Note  
corrosion of apron endwalls, with no  
epoxy coating. 1987





Station 976+40. Nodules of iron oxide characteristic of corrosion caused by anaerobic sulfate reducing bacteria at waterline on exposed steel of epoxy pipe. Water level recently lowered by removal of beaver dam. Inlet end. 1994





Station 976+40. Oxidation product at joints in aluminum pipe. 1994



Station 976+40. Beaver dam in epoxy bonded pipe. 1994





Station 976+40. Aluminized steel pipe. Organic-rich soil adhering to pipe. Pipes removed. 1995



Station 976+40. Inside of same section of pipe showing several perforations.





Station 976+40. Several small perforations in aluminized steel pipe associated with soil side corrosion in localities of organic rich sediment. This section of pipe disappeared between the culvert site and the county shop. 1995





Station 976+40. Five small perforations, not visible at this scale, and apparent failure of aluminum pipe during removal. Also noted was white corrosion product and thinning of metal. 1995

## **STATION 1111+70, WOOD COUNTY**

This site is just north of the town of Babcock. There are four pipes at this site, consisting of aluminum, polymeric coated, aluminized steel, and epoxy bonded. In 1975 the pipe at this site was a 23 inch (584 mm) by 37 inch (940 mm) galvanized steel pipe arch with heavy scaling of the invert. The pipe appeared to be a relatively recent replacement of an earlier (1941?) pipe. In 1975, a test for active SRB in the soil here was positive, but the principal cause of corrosion was uncertain. Flow at the inlet of the site appears to consist of some component of ground water seepage as evidenced by filamentous iron oxide in water in the pipes and in small pools of water at the upstream end of the site. Water flow at this site is commonly of low volume, but consistent, and originates from two separate sources, one from the north of the site and one from the south. Flow through the epoxy bonded and aluminized steel pipes is from the south and appears to consist of a greater component of ground water. Flow through the polymeric pipe and the aluminum pipe is from the north and appears to be predominantly surface water. At various times the greater flow volumes are through either the polymeric coated pipe or the aluminum pipe and through the aluminized steel or epoxy bonded pipe.

Water resistivity at this site is commonly high, and soil pH and resistivity are moderate. At times the water pH is low and at times the test for SRB in the soil is positive. In 1990 nodules characteristic of SRB in the water were observed on the exposed steel invert of the epoxy bonded pipe. In 1993 alkalinity of the water from north and south was about 5 mg/l. There appears to be a number of factors contributing to corrosion at this site.

This site is one half mile east of the Yellow River, and there is a possibility that during some years when the Yellow River floods during spring snow melt the flow directions in the pipe may reverse. The initial loss of coating on the epoxy bonded pipe was on the down stream or west end of the pipe and midway up the pipe, suggesting that initial loss of coating may have occurred from abrasion caused by ice during flood conditions on the Yellow River.

Photos of this site are on pages 25-31.

**STATION 111+70, STH 80, WOOD COUNTY  
ON-SITE TESTS**

DATE	pH		OHM cms		REDOX, MV		D.O. (ppm)	H <sub>2</sub> S test (soil)
	SOIL	WATER	SOIL	WATER	SOIL	WATER		
10/75	6.6	6.8	18,000	13,000				positive
5/81	6.1	5.7	18,000	30,000	+480	+570		strongly positive
INSTALLATION OF EXPERIMENTAL PIPE								
9/81	6.6	6.5	4,400	4,200	+250	+400	7	---
5/82	6.5	6.4	6,200	17,000	+320	+500		negative
5/83	5.8	4.4 N 4.8 S	3,800	30,000	+80	+500	11 N 9.5 S	positive
5/84	6.0	6.2	18,000	20,000	+140	+540	10	negative
5/85	6.3	5.5 N 6.0 S	6,600	45000N 28000S	+100	+400	9.5 N 7 S	strongly positive
5/86	6.5	6.3	4,600	12,000	+300	+600	5	strongly positive
5/87	6.6	6.4 N 6.7 S	10,000	24800N 11400S	+50	+350		positive
5/88	5.3	6.0	24,500	10,400	+60	little water		negative
5/89	6.6	6.5	8,000	11,100	+250	little water		negative
5/90	6.3	5.6 N 6.4 S	13,400	15100N 9400 S	+300	+500 N +370 S	9 N 7.5 S	negative
5/92	6.7	4.1 N 4.7 S	17,400	30200N 23500S	---	---	5	strongly positive
6/93	5.9	3.8 N 4.3 S	8,050	41500N 35500S	+150	+640	7.0 N 7.3 S	strongly positive

D.O. = Dissolved Oxygen

### Sodium and Chloride Values

DATE	Cl (ppm)	Na (ppm)
5/85	-0.5	1.5
5/89	8.0	6.7
5/90	9.0 North 20.0 South	5.7 12.3



Station 1111+70. West end. From left to right; aluminum, polymeric coated, aluminized steel and epoxy bonded.



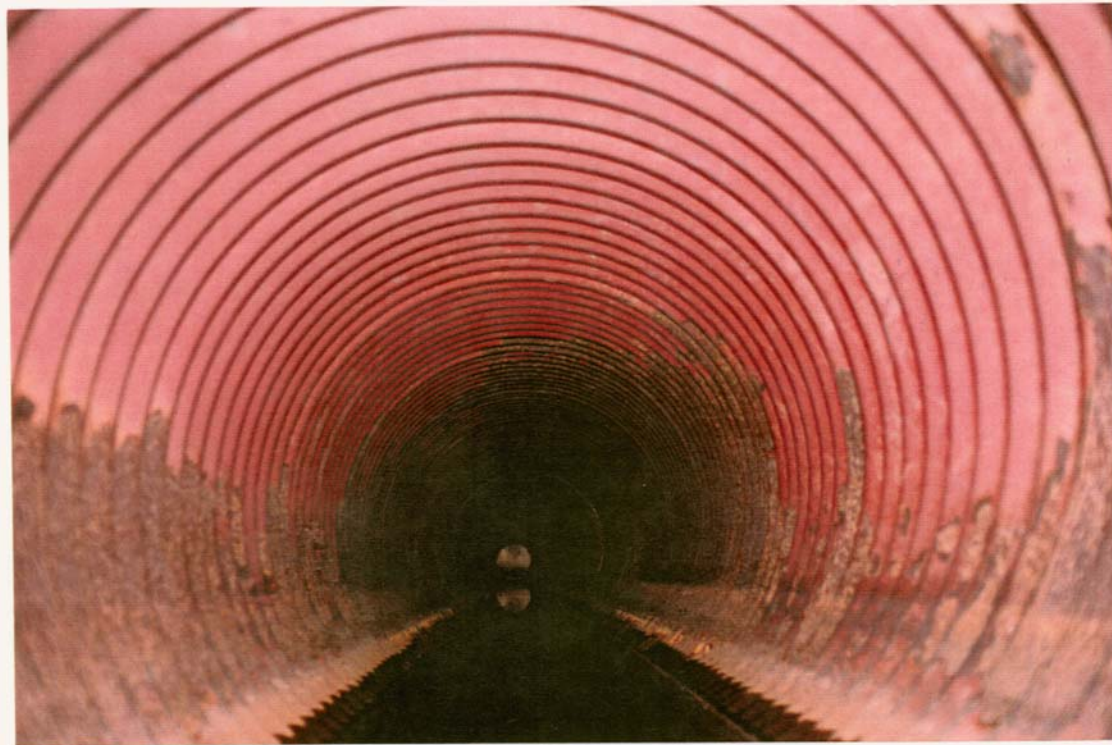


Station 1111+70. Loss of epoxy coating. West end. 1984



Station 1111+70. Enlarged area of coating loss. 1986



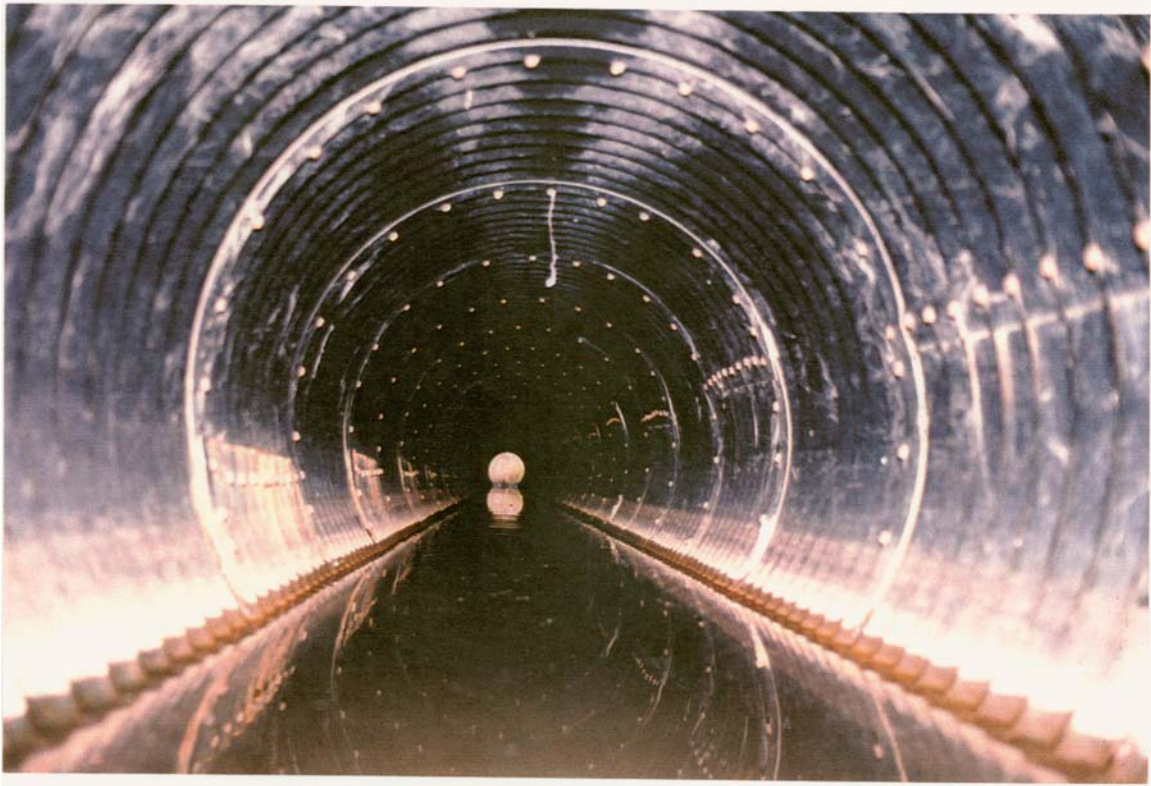


Station 1111+70. Epoxy bonded pipe with considerable loss of coating. 1994



Station 1111+70. Epoxy bonded pipe with SRB nodules forming along edge of invert where steel is exposed. 1994





Station 1111+70. Polymeric coated pipe. West end. 1994



Station 1111+70. Aluminized steel pipe with staining of crimped seams. 1994





Station 1111+70. Loss of barrier coating along edge of organic accumulation and development of pits on tops of corrugations beneath organic material in invert of aluminized steel pipe. 1994





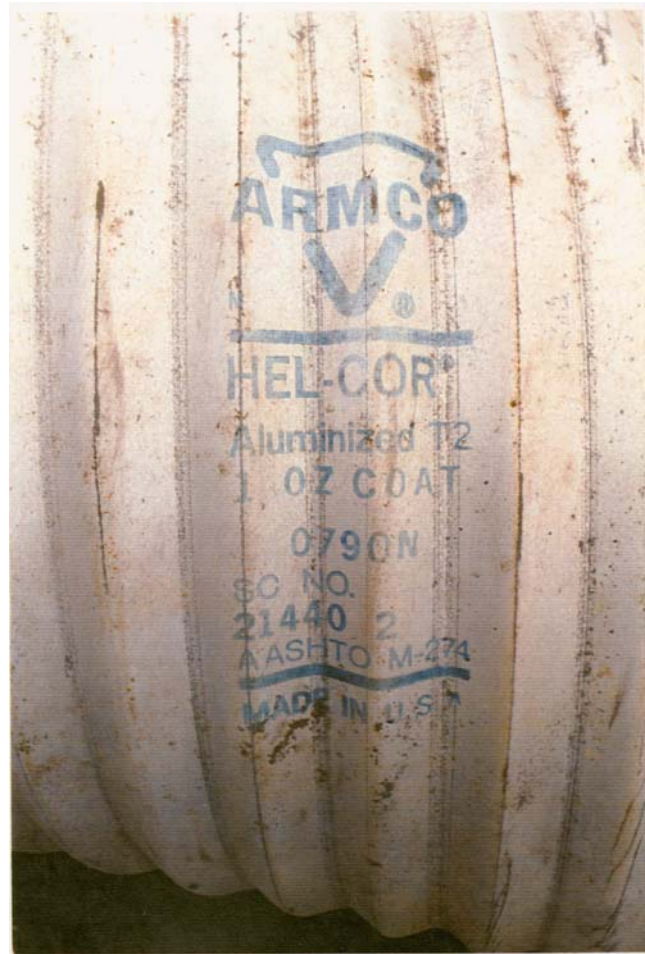
Station 1111+70. Aluminum pipe. No evidence of white precipitate at the joints in the roof of this pipe. 1994



Station 1111+70. Aluminum pipe. Minor pitting of cladding in invert. 1994



Station 1111+70. Specifications,  
aluminized steel and polymeric  
coated steel pipe.



## CONCLUSIONS AND OBSERVATIONS

Corrosion at these sites appears to result from multiple causes. Historically, corrosion of steel in the natural environment has been attributed to low pH and low electrical resistivity of soil and water. In addition, anaerobic sulfate reducing bacteria have been recognized to cause corrosion of steel in moist organic-rich soil. Corrosion caused by this type of bacteria is also very active in Wisconsin in surface water of low alkalinity (below 120 mg/l) and moderate pH, and apparently is made possible by the creation of anaerobic conditions on the metal surface by the development of biofilms produced by other organisms<sup>3</sup>. In addition, aluminum pipes are experiencing corrosion caused by NaCl deicer.

A problem with a study of this type is that years are involved before results are obtained, and during this period new products are developed and old products are modified or abandoned. In terms of comparison of performance of the four types of pipe at these three sites, the polymeric coated galvanized steel pipes evidenced the least distress. None of these pipes were perforated and removal of the coating was localized to the vicinities of exposed rivet heads and section ends. A totally coated pipe should improve performance.

The epoxy bonded pipes did not perforate but lost considerable coating at the two sites of flowing water and experienced advanced corrosion at joints at the site of equalizer pipes. The exposed areas of steel were subject to oxidation and to the activity of sulfate reducing bacteria. This type of coating is no longer in use.

The aluminized steel pipes experienced localized perforation at site 976+40 and localized pitting of the steel core at station 713+36 from the soil sides at localities with organic material in the fill. It appears that with this type of pipe the use of clean bedding and fill is especially important, particularly in moist environments. The aluminized steel pipe at station 1111+70 experienced pitting of the steel core on the water side of the invert, but this invert had been covered during the latter part of the study by up to several inches of organic soil. It appears likely that the pitting/perforation of these pipes at all three sites was due to the activity of anaerobic sulfate reducing bacteria in the soil. There was also some pitting of the invert of the aluminum pipe at station 713+36 in 1986 associated with a layer of organic material in the invert. The protective cover of aluminum is ascribed to the development of an aluminum oxide coating on the metal and this coating appears to be degraded in more strongly reducing environments.

The aluminum pipes evidenced the most severe distress from a source that was never considered when the pipes were installed. The removal of the pipes at the 713+36 site and the 976+40 site presented a much better opportunity to examine the pipes than if they had remained in place. Both aluminum pipes experienced appreciable thinning of metal in the roofs of the pipes. In addition, the pipe at site 713+36 had large perforations 3"-4" (76 mm -102 mm) in the roof and the pipe at site 976+40 had several small perforations. Before removal, the aluminum pipe at station 713+36 had a widespread coating of white precipitate on the inner roof of the pipe and the

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<sup>3</sup> Peng, C.G., Berthouex, P.M., and Park, J.K., 1993, *SO<sub>4</sub> Bacterial Corrosion in Partially Submerged Metal Structures*, Research Report prepared by the University of Wisconsin-Madison Dept. of Civil and Environmental Engineering for the Wisconsin Department of Transportation.

aluminum pipe at site 976+40 had a white precipitate at the joints on the inner roof of the pipe. This type of corrosion appears to be directly related to the use of NaCl as a chemical deicer. This precipitate consists principally of aluminum oxide, suggesting that the NaCl may act as a catalyst or at least act to increase the electrical conductivity of the soil adjacent to the pipe. At the time that this project was initiated there were many more aluminum pipes in service in Wisconsin than any of the other three types of experimental pipe on the project, but in 1980 their use was still considered to be a new application. The ironic aspect is that they proved to be very immune to corrosion in the natural environment. There has not been a reported case of perforation of an invert of an aluminum pipe from the water side in Wisconsin, but there were several aluminum pipes perforated from the soil side in areas of wet organic sandy soil on STH 54 in Wood County. These pipes had replaced zinc galvanized steel pipes which had been corroded by the actions of anaerobic sulfate reducing bacteria in the water. At this time, some aluminum culvert pipes are being installed in Wisconsin with protective covering laid over the top of the pipe.

The 16 gage galvanized steel apron end walls at all three sites experienced advanced corrosion, with some perforation, at station 713+36 which was not unexpected considering the performance of the original galvanized steel pipes at these sites.

Although corrosion at these sites appears to be the result of multiple mechanisms, corrosion of the aluminized steel pipes at these sites is associated with moist organic soil at sites where tests for anaerobic sulfate reducing bacteria in the soil were frequently positive. It appears that the type of pipe least susceptible to corrosion in this type of environment is a pipe with an organic barrier coating, as polymeric coated steel.



# **Appendix A**

## **EXPERIMENTAL CULVERT INSTALLATION WORK PLAN**

Wisconsin Department of Transportation

EXPERIMENTAL CULVERT INSTALLATION

WORK PLAN  
July 1980

OBJECTIVE

The purpose of this experimental evaluation is to compare the ability of several corrugated metal pipe materials to resist corrosion in locations of high corrosion potential. The materials to be evaluated are: 1) aluminum, 2) epoxy bonded steel, 3) aluminized steel, and 4) polymeric coated steel.

LOCATION

The replacement of existing culvert pipes with the experimental pipes is being done under two construction projects on STH 80 in Juneau and Wood Counties.

Project 1627-3-72  
Necedah-Yellow R.

Project 1624-3-71  
Babcock-Lonesome Road

These contracts, for a total of 22-1/2 miles of pavement recycling, include the installation of about 70 replacement culvert pipes. Three test sites have been selected for follow-up testing and will incorporate the experimental materials. The material used on the remainder of the culverts will be aluminum. The test sites are described below.

Site 1 - Station 713 + 36 (0.15 miles south of CTH "F"). This site will have two 30" pipes placed on a 15° skew, and constructed one-half each of one of the four materials. This site was selected because of low soil pH.

Site 1 - Station 976 + 40 (5.0 miles north of CTH "F"). This site will also have two 30" pipes placed on a 15° skew, and constructed one-half each of one of the four materials. This site was described as exhibiting bacterial corrosion in 1976.

Site 3 - Station 1111 + 70 (0.45 miles north of STH 173 East). This site will have four 30" pipes installed perpendicular to the centerline, one of each material. This site was described as unique and not representative of most of the other culvert sites on the project. The normal water source is a spring and the corrosive environment appears to be bacteria in this water. Heavy spring melt water flow has been experienced and the existing pipes are replacements for one that was washed out.

## BASIS OF EVALUATION

The basis of the evaluation of the durability of these culvert materials is two-fold: characterization of the culvert environment, and observations of the culvert pipe condition.

### Site Characterization

The following properties will be measured at each site to evaluate the culvert environment.

1. pH of the soil and water
2. electrical resistivity of the soil and water
3. oxygen reduction potential (redox) of the soil and water
4. sulphide content of the soil
5. sulfate content of the water
6. dissolved oxygen content of the water

Photographs will be taken at each site to illustrate the culvert layout and water flow conditions.

### Culvert Condition

The condition of the culvert pipes will be determined by visual observation, utilizing the attached corrosion rating scale. Any condition of the pipes that affects the flow of water through the culvert will be noted. Photographs will also be taken to document the observations of culvert conditions.

## CONTROL SECTION

In addition to using the aluminum culvert pipes as control pipes, it is proposed that galvanized steel endwalls will be installed on the experimental culvert types to serve as control tests.

## RESPONSIBILITY AND TIME SCHEDULE

### Construction Inspection

Copies of the construction inspection reports and observations made by project personnel during the installation of these experimental pipes will become part of the experimental project record. In addition, personnel from the District 4 Materials Section and Division of Highways Soils Unit will observe the site conditions and make the specified measurements prior to pipe installation and take photographs to document the initial site condition.



EXPERIMENTAL CULVERT INSTALLATION  
WORK PLAN  
Page 3

Follow-Up Evaluation & Reporting

The District 4 Materials Section and Division of Highways Soils Unit will be responsible for the follow-up observations and testing. The tests listed under "Site Characterization" will be repeated annually along with a condition survey of the culvert pipes and photographs of existing conditions. These inspections will be performed in late spring or early summer each year and a brief status report will be submitted by the district personnel to the State Experimental Projects coordinator in the Division of Highways Research Unit by September 1st. A final report will be prepared, presenting conclusions and recommendations to the Federal Highway Administration, 10 years after installation. It is the responsibility of the State Experimental Projects Coordinator to see that this final report is prepared and submitted to the Wisconsin Division FHWA office.

COST ESTIMATE

Initial inspection and testing is estimated to cost \$500 and the annual follow-up to cost \$300 each year, with the final report at 10 years adding an additional \$500. The total cost to evaluate these culverts would then be \$3,700.

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## CORROSION RATING CONDITION

<u>Corrosion Rating</u>	<u>Condition of Culvert Material</u>
0	No Corrosion--galvanizing (or other coating) still intact
1	Superficial Corrosion--no pitting
2	Moderate Corrosion--minor pitting, tight flakes
3	Fairly Heavy Corrosion--some pitting, tight flakes
4	Heavy Corrosion--deep pitting, but sound metal, flakes removed easily
5	Heavy Corrosion--deep pitting and unsound or perforated areas (unsound areas easily perforated with pointed object)
6	Small perforations exist
7	Large perforations exist
8	Invert complete corroded away